HoloOptics

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Wind power in cold regions

To De Ice or Not To De Ice

Wind power in cold regions benefits from high winds, high air density due to low temperature and often spaciously populated areas [1][2]. The main drawback is due to icing. Icing on wind power plants are causing power losses [1][2][3][4], increased wear [5] and is a public health hazard [6].

Two options are available for wind power plants in cold region. Accept the performance losses due to icing or fit the plant with de-icing equipment. The strategy to choose is dependent on many factors, but some of the more important are the total length of the icing periods at the chosen location and the amount of performance loss expected due to icing.

In this paper, the power loss due to icing at a wind power plant in Härnösand some 450 km north of Stockholm, Sweden is reported. At the plant were power output and the amount of ice on the plant monitored during the winter of 2008/2009. Approx. 20 periods with icing were recorded and the performance loss due to icing conditions, wind speed etc. was analysed.

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Presentation of the wind power plant and the sensors

On a wind power plant in the town of Härnösand approx. 450 km north of Stockholm, two HoloOptics Icing Rate Sensors was installed. Härnösand sits on the shore of the Baltic Sea and during the winter it is often subject to icing due to southern winds with high humidity content.

Along with the measurements with the two HoloOptics Clear Ice Indicators, the wind speeds and power outputs from the plant were measured. The wind speed and power output was sampled over ten minutes periods. The aim was to show the effect of icing on the power output.

The plant is a Vestas 600 kW installed 1997. It is situated at a small hill close to the town of Härnösand, see figure 1. At the hill is also a popular ski resort with a ski lift. Fine winter days several hundred persons are using the ski slopes and therefore ice throw is a real hazard. To counter this, the operator has developed a sophisticated routine in order to deter men when to shut down the plant.

Figure 1 the plant

The amount of ice was measured with two Icing Rate sensors. One of the sensors was without de-icing on the probe and the other was with de-icing on the probe. The sensors are mounted on the wind-power plant hub, see figure 2.

Fig 2 Ice Sensors installed on wind power plant

The sensor without de-icing is indicating (T21), as long as more than 15 µm of ice is present on the probe. It shows the length of the icing period. The sensor with de-icing is indicating (T23) each time the ice is 15 µm thick. The probe de-icing system is activated as long as ice is indicating. The de-icing system is turned on and off without time delay. This gives a typical pattern as shown in figure 3.The icing rate is calculated from this pattern.

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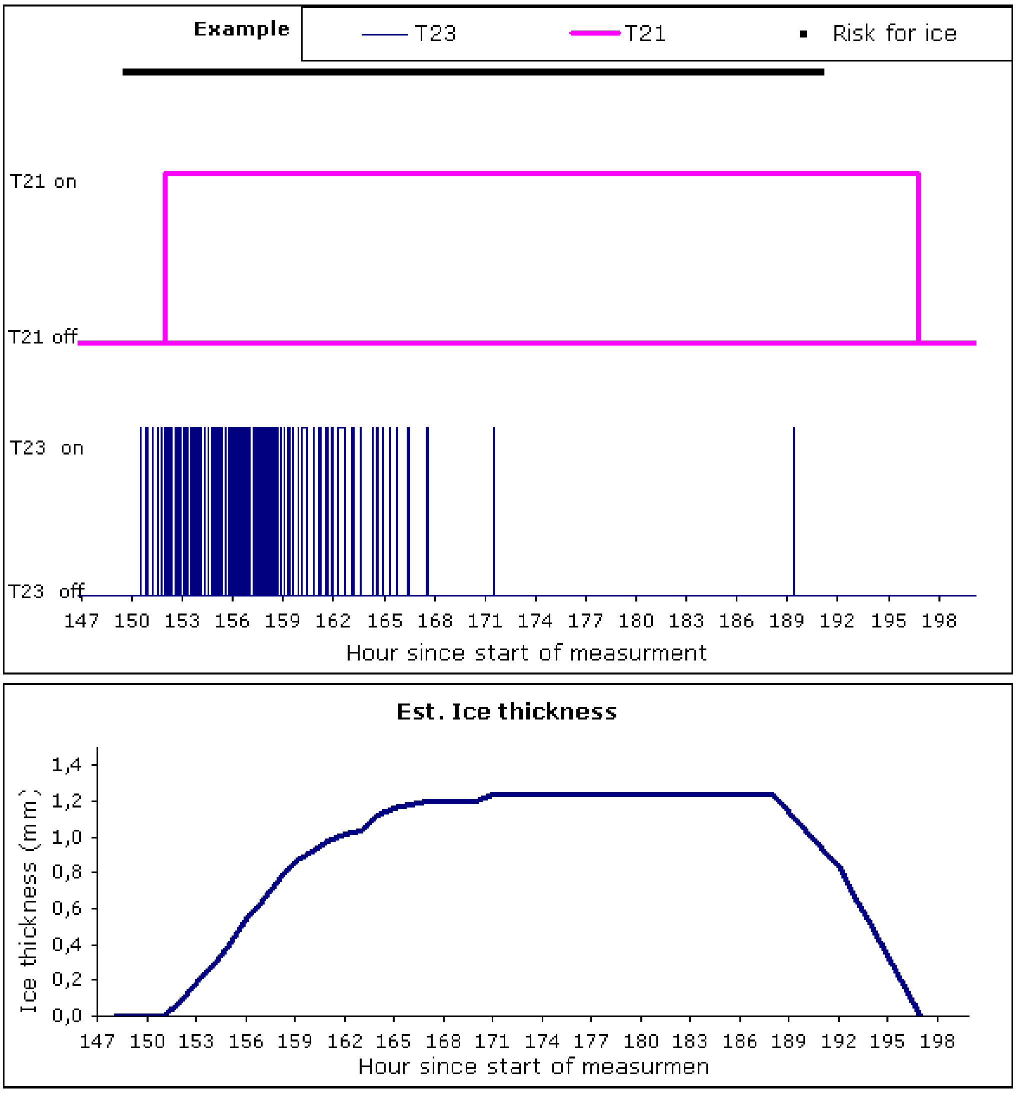

Fig. 3 Example of a period with light icing

Loss of power output due to icing, some results

The loss of power output due to icing is defined as the measured power output in relation to the expected, nominal, power output during the prevailing conditions.

If, during an icing period, the plant is closed due to high or low winds or due to maintenance the losses are not regarded as due to icing.

In theory the power output of a wind power plant is dependent to the third power of the wind speed. If the wind speed is below a specific minimum value the plant is shut down. At a specific wind speed, the rated wind speed, the plant is delivering its maximum power, the rated power. At very high wind speed, maximum wind speed, the plant is shut down.

In reality the relation is more complicated, as shown in figure 4. Apart from the wind speed the power output is dependent of air density, variations in wind speed and direction. Often the air turbulence has an impact on the power output. Air turbulence may vary with wind speed and direction.

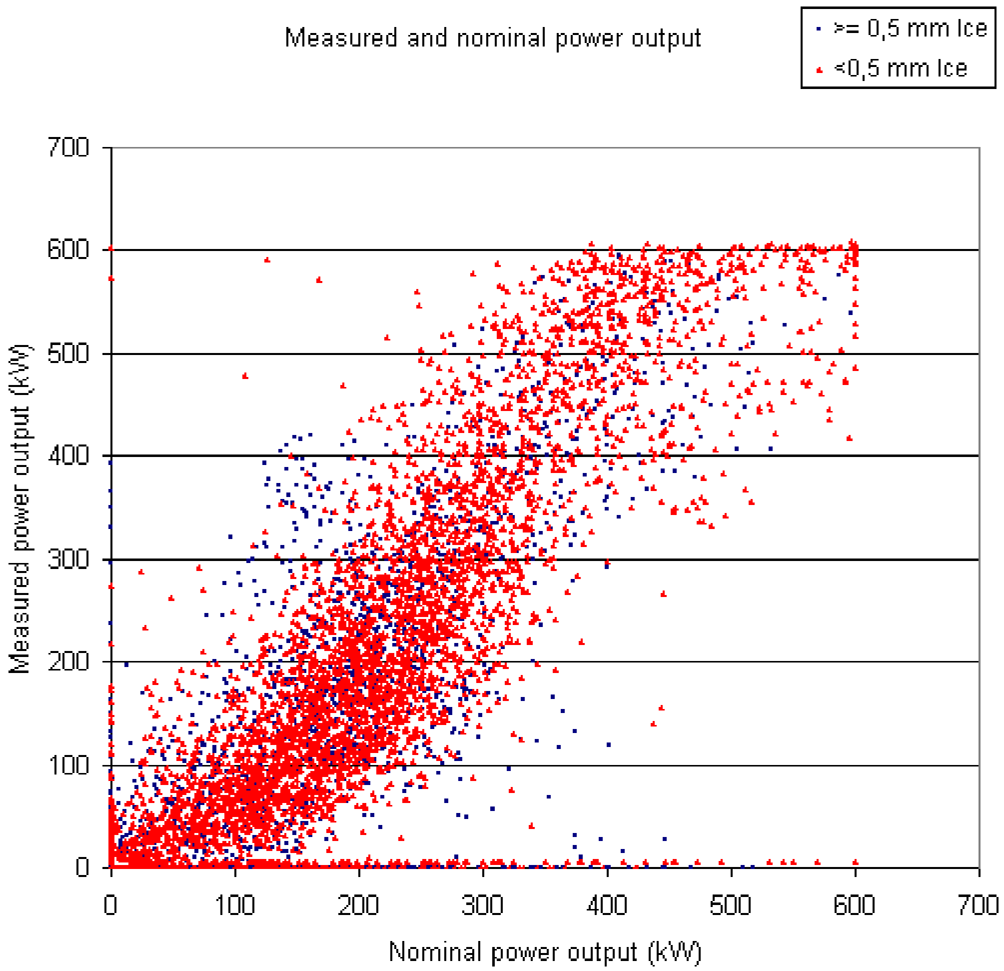

Fig 4. Measured and nominal power of the plant

Furthermore large errors may occur in the readings of the wind speed. Imperfections in the automatic control system are also common.

In this case the wind speed was measured at a mast situated some 400 m from the wind power plant. This may also incurs some errors. This was done, as it is difficult to measure the wind speed at the plant as it is severely disturbed by the rotor.
The existence of ice on the rotor blades has an impact to.

All these factors contribute to the blurred relation between wind speed and power output shown in figure 4.

The nominal power output is calculated by using wind speed and air density as given by the manufacturer.

One interesting fact in figure 4 is that the difference between measured power output and nominal power output over the period is approx. 6 %. At times with less than 0,5 mm ice on the rotor the difference is approx. 3 %.

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Test results

To investigate the power output losses, due to icing, every single period with icing are to be studied. In the following four of the periods with icing is studied in some details

Figure 5A and 5B shows two such periods.

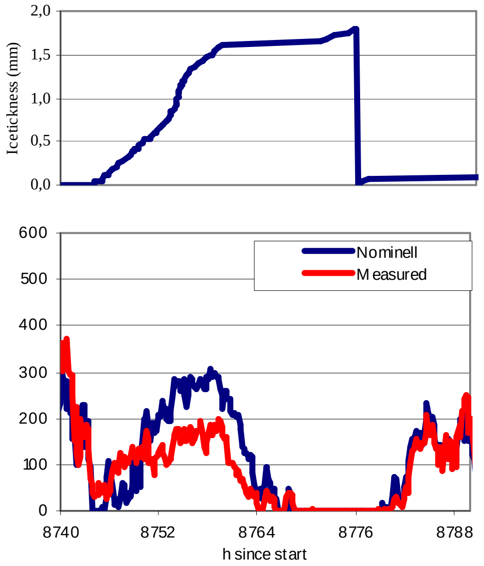

Fig 5A one period with light icing

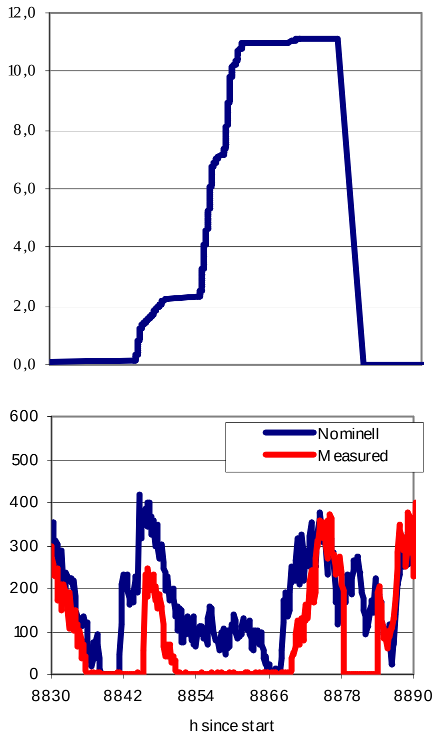

Fig 5B one period with heavy icing

Figure 5A shows that at the beginning of the icing period there are no losses. In fact the measured power output is larger than the nominal. As the ice gets thicker than 1 mm the measured the power output is clearly reduced. At 1,5 mm of ice the power loss is approx. 40%, regardless of wind speed.

During the end of the icing period in figure 5A, the wind speed is lower than minimum value. The closure of the plant is not due to icing.

If the ice thickness is more than 3-4 mm the operator closed the plant, as the operating costs is higher than the value of the energy produced. This is shown in figure 5B.

The reason closure of the plant around 8842 hour in figure 5B is not due to icing.

As the ice is melted the measured power is close to the nominal. This is clearly shown in both figure 5A and 5B.

By manual inspection it was deter mend that the plant was covered by rime ice during both periods shown in figure 5A and 5B. Rime ice is more rugged than clear ice. Rime ice will therefore induce more losses than clear ice at the same thickness.

In figure 6A and 6B two other periods with medium and heavy icing are shown. In this case the ice is mostly clear ice.

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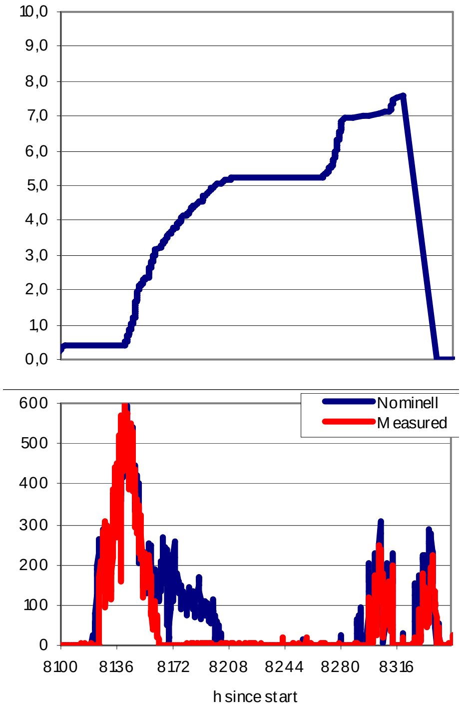

Fig 6A Medium to heavy icing

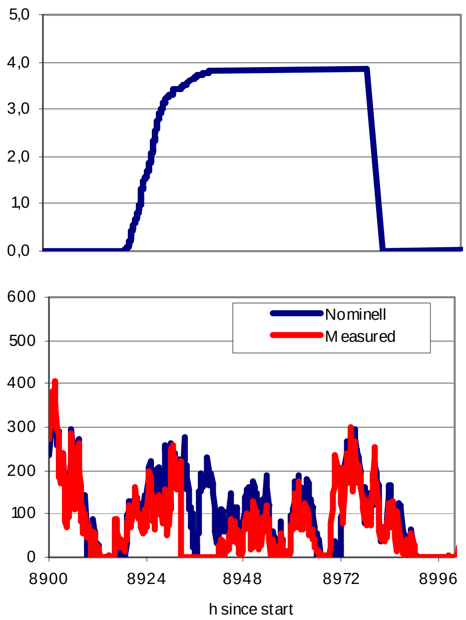

Fig 6B Light to medium icing

Figure 6A shows a period with medium to heavy icing but the power losses due to icing is small. The closure of the plant is during most of the time due to the wind speed, which is lower than minimum value, and not due to icing.

In Figure 6B the power loss is lower than expected. This is explained by the fact that the plant is covered with clear ice.

Summary of the test

The plant in Härnösand was found to have a loss of energy output of approx. 15 % during January to March 2009, due to icing. Included are times with the plant was shut down due to risk for ice throw. More than 0,5 mm of ice was noted in approx. 505 hours out of a total of approx. 2 200 hour. Any icing during the rest of the year is very light and has no impact on the plant.

The loss of electric energy output over one year is estimated to approx. 5 %. Of the energy losses approx. 35 % is due to the closing down of the plant due to the risk of ice throw.

The electricity energy output is approx. 1 200 MWh per year. Today its value is 45 000 € per year. The losses due to icing is 2 200 €. Over a 15 year period with 5 % interest that is 25 000 €. This is 3-5 % of the total installation cost.

Icing during longer periods or higher value of the electric energy output makes de-icing more interesting.

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Risk for Ice throw

Ice throw is a public health risk associated with wind power in cloud climate. In some countries the subject is due to regulations. In spacey populated areas some warning signs may be sufficient, see figure 7.

Fig 7 Warning sign

According to [6] the area exposited to the risk of ice throw depends on wind speed and the size of the plant.

As the tested plant is close to a popular ski resort, security is at highest import ants. Therefore the plant is shut down during daytimes with fine weather with ice indicated. The total energy output losses are 1,5 % on a yearly basis.

Conclusions

The most important factor in the calculation of losses in the electric energy output due to icing is how many hours per year the ice thickness is more than 1 mm or 2-3 mm if the plant is large. It is reasonable to believe that a larger plant (larger rotors) is less sensitive to icing. This is not confirmed by this test.

The type of ice and the wind speed during the icing periods is also of important.

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With 500 hours of icing per year de-icing is economical viable if the cost of installation is less than 40 000 € per MW rated power. Calculated over 15 years and 35 € per MWh.

If icing is more common or if the value of the electric energy output is higher, then a higher installation cost due to the installation of de icing equipment may be accepted.

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